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Background interference from car carpets—the evidential value of petrol residues in cases of suspected vehicle arson

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Abstract

This study was undertaken to test the theory that there is a natural occurrence of petrol on the carpet or carpet mats of motor vehicles that would interfere with the potential determination of arson residues. Part of this study was also to determine what levels of background interference due to the carpet matrix are likely to be encountered in the general population of motor vehicles. The study was conducted in three parts.

1. A persistence study was conducted to determine the evaporation and persistence of unleaded petrol on carpet. The results indicate that small volumes of petrol (less than 100 μl) are unlikely to be detected on carpet after a 24 h period. Larger volumes will be detected after this period, but will generally not be detectable after 1 week.
2. A known history study was conducted by the insertion of carpet mats, for varying lengths of time, into the driver area of separate vehicles, with subsequent analysis for the presence of petrol. A 'history' sheet was completed by the occupants of the vehicles during the insertion periods to record the frequency of contact with petrol, and general usage of the vehicles. The results indicate that petrol will not normally be found on previously uncontaminated carpet mats after a 6-week period of use in a vehicle, however, the occupation and behaviour of the occupants can affect the types of compounds deposited onto the carpet.
3. An unknown history study was conducted via the collection of carpet or carpet mat samples from vehicles with an unknown history, and subsequent analysis for the presence of petrol. Six of the 150 samples examined contained petrol. These results indicate that only a small proportion of motor vehicles will exhibit the presence of petrol on carpet or carpet mats, and then only as evaporated petrol.

All of the above findings increase the evidential value of finding significant volumes of fresh or slightly evaporated petrol on carpet products in motor vehicles.

Keywords: Carpet; Motor vehicles; Arson; Fire; Petrol; Gasoline; Accelerants; Matrix interference

1. Introduction

One of the major objectives in the investigation of any suspected arson is the isolation and identification of residual accelerants from the fire debris. A recent study of laboratory casework [1] determined that out of 1040 individual items submitted for analysis, 17.6% were from motor vehicles, and of these motor vehicle sample items, 48.1% contained ignitable liquid residues. Petrol (gasoline) was the most frequently detected ignitable liquid, accounting for 78.4% of positive results in motor vehicle samples [1]. Similar results have been reported by other forensic laboratories [2].

Carpet and carpet padding have strong absorption and retention qualities, which make them ideal for ignitable residue sampling. Current literature varies with respect to the volume of samples submitted that contain carpet or carpet materials. Jackowski [1] reports the incidence at 15%, while Bertsch and Zhang [3] found that 60% of samples

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submitted to laboratories contain carpet materials. The response to a survey in this research, sent to all state forensic laboratories in Australia, indicated that 10–20% of samples received contain carpet materials.

Carpet is a woven composite material manufactured from a variety of materials. Many modern carpets and carpet padding are of petrochemical origin and therefore, may share molecular similarities with many ignitable liquids. When exposed to heat, these materials can decompose to produce numerous volatile compounds, which can complicate the identification of any accelerants that may be present.

Interference from background materials falls into two basic categories [4]. The first is from actual petroleum products present in the substrate material, and the second, substrate materials that pyrolyse to form volatile compounds in the range of common ignitable liquids. A number of studies have illustrated the complicating effects that the presence of volatile pyrolysates from carpets can have on the identification of ignitable liquids. Bertsch [5] investigated the nature of volatiles produced during the pyrolysis of carpet material. He found that while the fibre in carpets did not produce significant amounts of hydrocarbons, the backings often did, generating copious amounts of alkylbenzenes, benzene, toluene, ethylbenzene, styrene and alkylstyrenes, naphthalene and methylnaphthalenes, and other diagnostic components of petrol. It was also found that different carpets do not always produce the same interferences.

In an investigation by DeHaan and Bonarius [6] into the different pyrolysis products of structure fires, it was determined that various carpets can produce complex mid-range mixtures of hydrocarbons in readily detectable quantities. This can increase the complexity of identifying the presence of ignitable liquids in samples containing these materials.

Few studies, however, have investigated the backgrounds produced by unburnt carpets. Lentini et al. [4] investigated the volatile components detectable in a wide variety of common objects, ranging from household products to shoes, clothes and carpet. They concluded that carpet samples can contain a number of compounds found in petrol. The aforementioned study by Bertsch [5] also indicated that unburnt carpet can produce discernible levels of petroleum-type hydrocarbons.

Just as the absence of accelerants in fire debris does not prove that an accelerant was not employed, the presence of residual 'accelerants' in fire debris is not a definitive indicator of arson. There may be perfectly legitimate reasons as to why accelerant components are present. The significance of the presence of petrol in motor vehicle fires has been challenged due to the possibility of natural occurrence of petrol residues inside the vehicle. Possible sources of petrol include the emissions from the vehicle itself, spillage into the boot and passenger compartments due to cracking or loosening of the rubber connection between the fuel tank and filler spout [7], transfer from objects such as jerry cans carried in the vehicle, and petrol transferred from the external environment via the shoes of the driver and passengers.

Unlike other trace evidence such as glass and fibres, few persistence studies have been performed investigating the evaporation rate of petrol from various materials. The evaporation of petrol from soil has been examined [8,9], and studies have been performed regarding the transfer and persistence of petrol on hands after filling a car [10], and on clothing and shoes while pouring petrol around a room [11]. It appears, however, that there has been no research on the potential transfer of petrol onto motor vehicle carpets and little on the persistence of petrol on carpet itself. A study by Folkman et al. [12] discovered that petrol was detectable on shoes after a period of 48 h, and on carpet after 7 days. The carpet in that study was left in an outdoors environment, at temperatures ranging from 5 to 15 °C.

Given the above factors, the determination of the significance and evidential value of petrol residues on vehicle carpet in the case of motor vehicle fires requires consideration of the following: ''What is the probability that the carpet in the motor vehicle had a naturally occurring background level of petrol as a result of everyday use?''

2. Materials and methods

2.1. General

Carpet samples of known and unknown history were collected from a variety of motor vehicles and examined for the presence of trace amounts of petrol. The sampling technique used was a passive adsorption/elution technique utilising activated charcoal to concentrate the volatile products, followed by elution with a solvent. The resulting extracts were analysed using gas chromatography–mass spectrometry (GC–MS).

2.2. Samples of unknown history

A total of 150 samples from vehicles with unknown histories were examined to determine whether petrol was present, and what types of chromatographic profiles could be encountered. The samples were collected from vehicles at insurance salvage yards. Motor vehicles owned by insurance companies were chosen due to the destructive nature of the sampling, and the fact that such organisations acquire vehicles from a diverse population. A 15 cm × 15 cm sample was removed from the existing carpet where possible, or from any car mats present if the vehicle or contents were to be resold. The area from which the carpet was excised was chosen to approximate the position in which the average person would place their feet. The make, model and condition of each vehicle sampled were noted in a numbered table, with each carpet sample being numbered consecutively. The samples consisted of either original car carpet (41 samples), or carpet car mats (109 samples) removed from 54

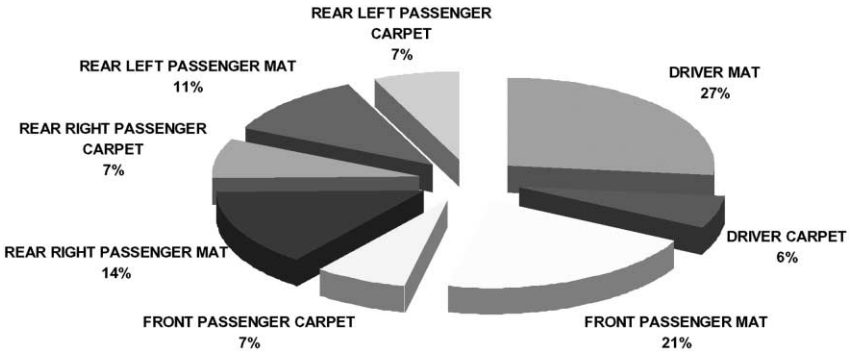

Fig. 1. Unknown history sample type and collection position.

different vehicles. In total, there were 49 samples removed from the driver well, 42 from the front passenger well, and 32 and 27 removed from the rear right passenger and rear left passenger wells, respectively. It was not possible, in every case, to take samples from all four positions in a vehicle. A breakdown of sample types and vehicle positions is given in Fig. 1.

The samples in the unknown history study could be further classified, according to their physical appearance, into nine different classes as indicated in Table 1.

The distribution of the vehicle makes in the sample population was similar to that found in the Australian motor vehicle population [13].

2.3. Samples of known history

A total of 17 car mats were obtained for insertion into the driver wells of volunteer vehicles. Fifteen car mats were donated by a manufacturer of automotive interiors, and two were purchased from a retail store. The mats inserted into the vehicles could be classified into four different categories based on physical appearance, and exhibited three distinct chromatographic profiles. The clean car mats were allocated a number and analysed using adsorption/elution followed by GC–MS analysis to determine the level of background interference due to their composition. Each car mat was then placed in the appropriate area of a specific vehicle, and the model, make and area noted on a data sheet. The driver of each vehicle was given a history sheet to record each time the vehicle was refuelled, by whom (passenger or driver), and any unusual events during the daily usage of their vehicle. The mats were removed after a certain time period and placed in clean, labelled paint cans. The samples were then subjected to the aforementioned absorption/elution procedure followed by GC–MS analysis of the extracts for the presence of petrol.

2.4. Laboratory analysis of collected samples

An analytical procedure consistent with relevant ASTM guidelines [14–16] was adopted in this study for the detection and identification of volatile hydrocarbons.

2.4.1. Passive headspace concentration—adsorption

A DFLEX® device or activated charcoal strip (ACS), obtained from ALBRAYCO Materials Analysis Laboratories Inc. (Connecticut, USA), was added to the carpet sample in each paint can. The sealed can was then placed in an oven and heated at a temperature of 60 °C for 16 h [17,18]. Nine cans were placed in the oven at once, and a blank DFLEX® was also heated in an empty paint can to ensure no cross contamination occurred. Once cooled to room temperature, the DFLEX® was removed and the elution process carried out.

Table 1
Physical appearance categories

Class	Description
1	Carpet, thin or medium thickness, Hessian-like backing
2	Carpet, thin or medium thickness, rubber backing
3	Carpet, thin or medium thickness, adhesive layer evident, felt-like backing
4	Carpet, thin or medium thickness, rubber-like coating on back surface
5	Carpet, thin to medium thickness, multi-coloured padding, adhesive layer evident
6	Carpet, thin to medium thickness, waxy backing
7	Carpet, thin to medium thickness, thick rubber backing
8	Thin brown fabric (stocking-like) stretched over thick rubber backing
9	Carpet, medium thickness, foam-like backing, adhesive layer evident

Table 2
Instrumental parameters

Injector temperature	250 °C
Detector temperature	250 °C
Flow rate	1.7 ml/min at 50 °C
Split flow	25 ml/min
Injection volume	1 μl
Split ratio	15.7:1
Oven program	
Initial	50 °C for 2 min
Ramp	10 °C/min to 160 °C
Ramp	70 °C/min to 290 °C
Final	290 °C for 4.14 min
Mass spectrometer on	1.75 min (solvent delay)
Mass spectrometer off	13 min
Scan mode–scan range	40–200 amu

2.4.2. Passive headspace concentration—elution

The charcoal strip was removed and placed into a 2 ml labelled vial with 800 μl of carbon disulphide (CS_2) containing 1% (v/v) 2-hexanone as an internal standard. The extract was then transferred to a labelled auto-sampler vial for analysis by GC–MS.

2.4.3. Gas chromatography–mass spectrometry instrumentation

The GC–MS analysis was performed on a Hewlett-Packard 5890 Series II gas chromatograph fitted with a Hewlett-Packard 7673 auto-injector and interfaced to a Hewlett-Packard 5970 Series mass selective detector. The GC was fitted with a DB-5 ms 30 mm × 0.25 mm i.d. capillary column (film thickness 0.25 μm) using helium as the carrier gas. MS ChemStation software, version G1034C (Hewlett-Packard), was used for data analysis. Specific operating parameters were as indicated in Table 2.

2.4.4. Data analysis

With reference to ASTM guidelines E 1387 and E 1618, the target compounds indicated in Table 3 and Fig. 2 were chosen to determine the presence or absence of petrol.

Total ion chromatograms were obtained for each sample and these were evaluated by visual pattern matching against known standards. The identity of each target compound was then confirmed by searching their mass spectra against a reference library. All major peaks (minimum level, three times the baseline noise [19]) were identified using mass spectral data and recorded for each sample chromatogram. Extracted ion profiles were obtained in order to reduce interference from background volatiles. Appropriate characteristic ions were chosen as per ASTM guideline E 1618. The resultant profiles were compared to those of known petrol standards.

The degree of evaporation can affect the presence of the lighter and heavier compounds, and thus, the absence of compounds at the light or heavy end did not necessarily exclude the presence of petrol. Absence of the intermediate components, most particularly the trimethylbenzenes and tetramethylbenzenes, did however, preclude the presence of petrol.

2.5. Persistence study

The evaporation rate of petrol from carpet was studied under controlled conditions. Known volumes of unleaded petrol were placed on eight 15 cm × 15 cm sections of carpet car mat. Passive adsorption/elution followed by GC–MS was used to determine the chromatographic profile at various stages of evaporation. The volumes of unleaded petrol added were 0, 10, 50 and 100 μl, and the samples were left for periods ranging from 24 h to 4 weeks. The carpet mat pieces were kept indoors in separate rooms, and the temperature recorded at regular intervals. The car mats were obtained from the same manufacturer and were of the same type as the mats used in the known sample study.

Evaporated petrol standards were prepared (60, 90 and 99% evaporated petrol) then 15 μl of each evaporated solution placed on a tissue in a clean paint can. These samples were subjected to the same adsorption/elution procedure

Table 3
Unleaded petrol target compounds for identification

Number	Target compound	Number	Target compound
1	Toluene	13	1,3-Diethylbenzene
2	Ethylbenzene	14	1-Methyl-3-propylbenzene
3	*m*-Xylene, *p*-xylene	15	1,4-Diethylbenzene
4	*o*-Xylene	16	4-Ethyl-1,3-dimethylbenzene
5	Propylbenzene	17	4-Ethyl-1,2-dimethylbenzene
6	1-Ethyl-3-methylbenzene	18	2-Ethyl-1,3-dimethylbenzene
7	1-Ethyl-4-methylbenzene	19	1,2,4,5-Tetramethylbenzene
8	1,3,5-Trimethylbenzene	20	1,2,3,5-Tetramethylbenzene
9	1-Ethyl-2-methylbenzene	21	Naphthalene
10	1,2,4-Trimethylbenzene	22	2-Methylnaphthalene
11	1,2,3-Trimethylbenzene	23	1-Methylnaphthalene
12	Indane		

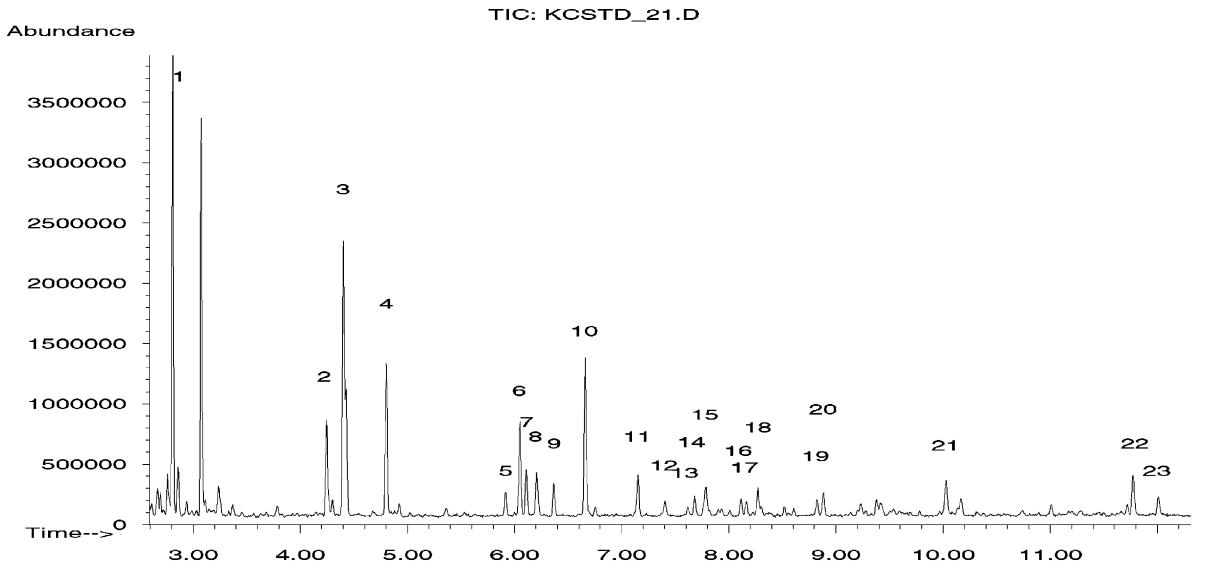

Fig. 2. Chromatogram of fresh unleaded petrol, indicating target compounds.

described above. The extracts were analysed using GC–MS to obtain chromatographic profiles for comparison purposes.

3. Results—background interference

All of the mats in the known history study were obtained from the manufacturer, except mats 3 and 9, which were purchased from a retail store. The mats obtained directly from the manufacturer exhibited much stronger levels of background volatiles than those purchased. While this may have been due to a number of factors, little was known regarding the history of the mats before being received (i.e. time since manufacture, storage conditions, etc.) and therefore, no comments could be made as to the source of this background.

The low levels exhibited by the two purchased mats may have been due to the fact that, for a period of 4 weeks after purchase, the mats were stored in a clean empty cupboard before analysis of background volatiles and insertion into a vehicle. The background profile was determined immediately after purchase, and then again just prior to insertion into a vehicle. During this time period, the more volatile compounds would have been released from the carpet matrix. The change in chromatographic intensity over this time period is illustrated in Fig. 3.

The level of background interference from all of the carpet matrices decreased visibly with time, especially with the mats obtained from the manufacturer. Comparison of the background present before insertion to that visible after insertion showed a noticeable reduction in interference levels. During the period of insertion, it appears that the more volatile components have been released from the carpet matrix, to such an extent that they no longer present significant levels of potential interference in the chromatographic profile. This is particularly evident in the results obtained from the samples inserted into vehicles for 6 weeks, as shown in Fig. 4.

The carpet mats from which the persistence samples were taken were of two different types, however, they displayed similar background chromatographic profiles. Both mats were composed of dark grey carpet of medium thickness, one with a rubber backing, and the other a felt-like backing with a visible adhesive layer between the two material layers. As with the samples for the known history studies, both mats were obtained directly from the manufacturer and initially displayed significant levels of background volatiles (Fig. 5). These levels decreased noticeably with time and very few volatile compounds could be detected after 1 month.

3.1. Persistence study

Only two of the persistence samples exhibited traces of petrol. Both samples had been doped with 100 μl of petrol and analysed after 1 day. For both samples, the decreased abundance of the more volatile components such as toluene and the trimethylbenzenes indicated that significant evaporation of the petrol had occurred. Both samples showed chromatographic profiles similar to that of between 60 and 90% evaporated petrol.

With one of the samples that exhibited evidence of the presence of petrol, a number of the target compounds eluted at similar times to matrix background compounds, thus, masking their presence (Fig. 6). Examination of peak purity in the area at which the tetramethylbenzene target compounds elute (7.0–9.0 min) indicated that a number of

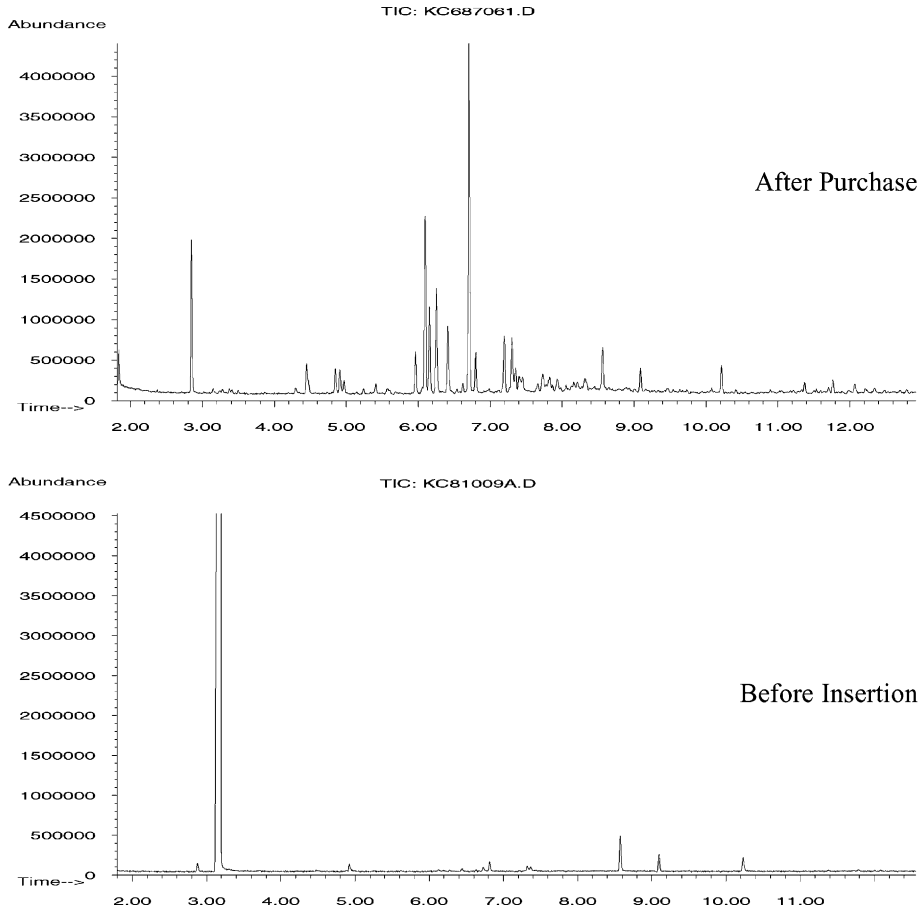

Fig. 3. Comparison of car mat background profile after purchase and before insertion into vehicle.

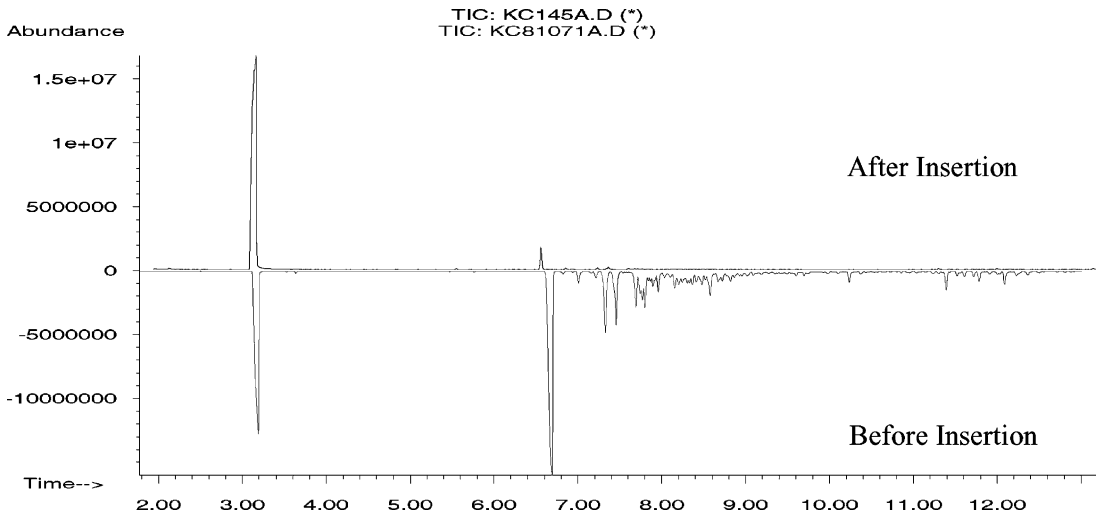

Fig. 4. Chromatographic profile of known history sample, after insertion for 6 weeks, and mirror image chromatogram of background before insertion.

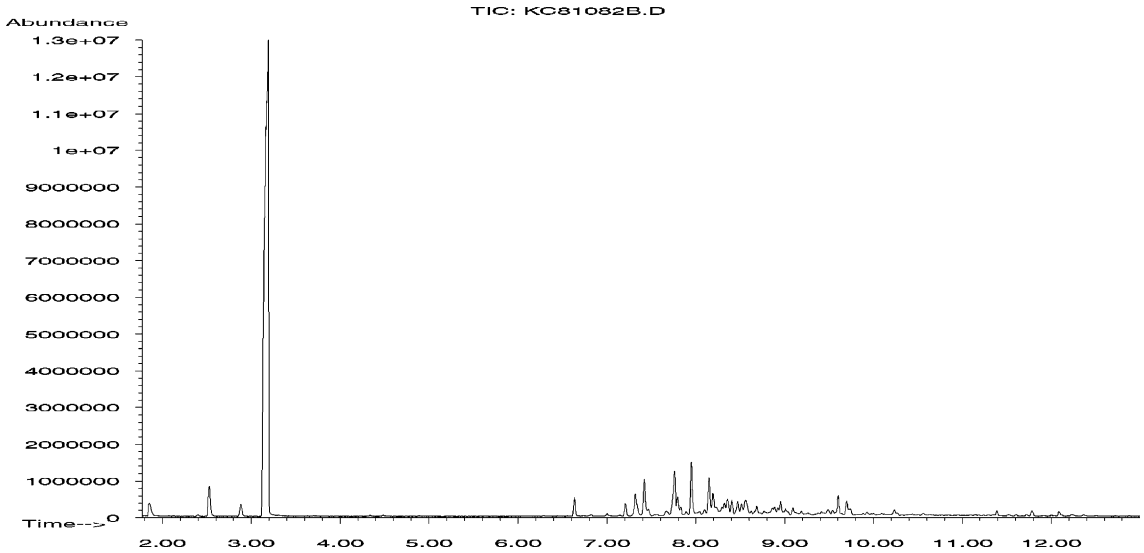

Fig. 5. Chromatographic profile of persistence sample background volatiles.

peaks contained multiple compounds. A clearer pattern emerged through the use of an extracted ion chromatogram, and this was compared to an extracted ion chromatogram for a known sample of evaporated petrol.

3.2. Known history study

While all carpet mats exhibited decreased levels of background volatiles after the specified insertion period in the vehicle, analysis showed that 8 of the 17 mats contained low levels of new compounds not present in the initial chromatographic profile (Table 4).

The most common new compounds were *m*-, *p*- and *o*-xylene, and limonene. All of the mats inserted for 1 week that contained new compounds showed the presence of *m*-, *p*-xylene, while five of the six mats inserted for longer periods, which contained new compounds, showed the presence of all three xylenes. Analysis of the results does not show any relationship between mat type and the absorption/retention properties of the mats with respect to compounds found in petrol.

After the insertion period, three of the mats exhibited a number of the target compounds present in petrol that were not present in the initial profiles. Analysis showed the

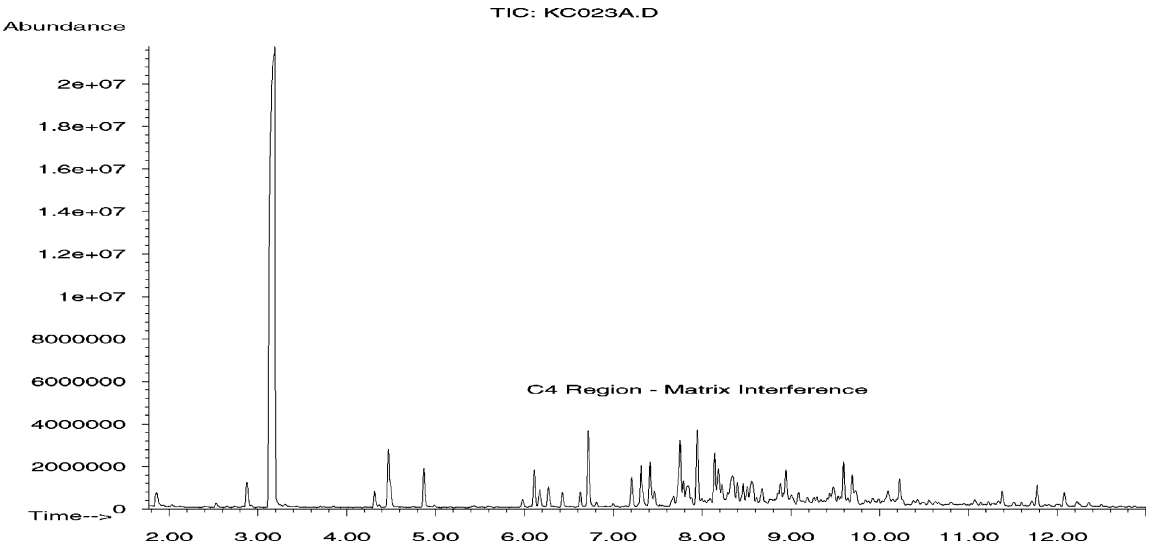

Fig. 6. Chromatogram of persistence sample (100 μl petrol, 1 day), showing a chromatographic profile similar to that of 60% evaporated petrol.

Table 4
Summary of known history sample analysis

Mat	Insertion period (week)	Fuel entries	Profile changes
83	1	3	New compounds
87	1	3	New compounds
3	1	1	New compounds
77	1	1	New compounds
79	1	0	Decrease
76	2	2	Decrease
85	2	0	Decrease
84	3	2	Decrease
74	3	3	New compounds
3	4	2	Decrease
9	4	5	New compounds
78	4	5	Decrease
83	4	5	New compounds
87	4	5	New compounds
88	6	1	Decrease
75	6	6	New compounds
71	6	6	Decrease
72	6	4	Decrease
81	6	6	New compounds
73	6	6	Decrease

presence of some or all of the following compounds: toluene, ethylbenzene, *m*-, *p*- and *o*-xylene, 1-ethyl-3-methylbenzene, 1-ethyl-4-methylbenzene, 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene and 1,2,3-trimethylbenzene. Two of the mats also exhibited α-pinene and/or eucalyptol after the insertion period.

The mat exhibiting the most target compounds was removed from a vehicle that was filled six times during the 6-week insertion period (an average of once per week). The driver of the vehicle worked as a mechanic, and recorded wearing his work boots in the vehicle a number of times. He also recorded carrying motor vehicle parts in the vehicle (position not indicated). These behaviours may account for the presence of a number of petrol target compounds. The driver also recorded cleaning the interior of the vehicle, which may account for the presence of limonene, a common solvent in carpet cleaning products and adhesives. In fact, all of the mats placed in vehicles that were washed during the insertion period showed the presence of limonene. While some trends are indicated, the limited sample size precludes the drawing of any conclusions with respect to variables such as carpet type and vehicle refuelling frequency.

3.3. Unknown sample study

The following classification of background chromatographic profiles was applied during the interpretation of results:

- NIL: no major compounds present.
- SIMPLE: contains less than 10 major compounds.
- MATRIX INTERFERENCE (MI): exhibits large group of unresolved peaks in the region between 6 and 12 min (depending on level of interference), mainly branched and straight-chain, saturated and unsaturated hydrocarbons.
- TARGET COMPOUNDS: exhibits five or more target compounds (but not all) required for the identification of petrol.
- PETROL: exhibits all of the target compounds required for the identification of petrol.

The results obtained from the analysis of the 150 unknown carpet samples are summarised in Tables 5 and 6.

Examination of this data indicates that a significantly lower percentage of the original car carpet samples (12%), than car mats (45%), exhibit background profiles that would complicate the interpretation of samples containing petrol. The results also indicate that car mats exhibit higher levels of target compounds (16%) and petrol (5%) than do original vehicle carpets (12 and 2%, respectively). Only six of the unknown samples (representing 4% of the total number) were determined to contain petrol. Of these, only one sample was original carpet, and the remaining samples were carpet car mats.

3.4. Matrix interference

The interference exhibited by 35% of the unknown samples examined was determined to be due to numerous branched and straight-chain saturated and unsaturated hydrocarbons eluting between 6 and 12 min. This is the region in which the heavier components of petrol are found, most importantly for identification the C3- and C4-benzenes. As can be seen from the chromatogram depicted in Fig. 7, this interference can be quite severe.

While sample types 1 and 4 showed levels of matrix interference that could potentially complicate interpretation of the chromatogram, less than 8% of each type (3.6 and 7.1%, respectively) exhibited significant numbers of petrol target compounds. As such, the use of an extracted ion chromatogram would reduce this interference and considerably simplify the interpretation process.

3.5. Target compounds

While a number of samples exhibited the presence of some (between 2 and 10) of the target compounds required for the identification of petrol, close examination indicated that petrol was not present. Inspection of the relative ratios of compounds, either in the total ion chromatograms or extracted ion chromatograms, prevent these profiles from being mistaken for that of petrol. Comparison with fresh and evaporated petrol standards indicate the changes in relative ratios are not due to weathering effects.

Seven of the samples analysed (4.6%), however, exhibited the majority of the target compounds required, and in the correct ratios. Six of the seven samples were car mat samples, two from the driver well (29%), and four from the front passenger well (57%). The remaining sample, a type 5 original vehicle carpet sample, was from the rear right

Table 5
Summary of unknown history sample analysis

No.	Position	Substrate	Type	Vehicle	Condition	Result
1	Driver	Carpet	5	Mazda 626	Motor parts throughout interior	Simple
2	FS passenger	Carpet	5	Mazda 626	No doors on vehicle	Matrix
3	RR passenger	Carpet	5	Mazda 626	No doors on vehicle	Nil
4	FS passenger	Carpet	1	Ford Falcon	Fire damage to seats	Matrix
5	Driver	Carpet	5	Ford Falcon	Odour of petrol	Petrol
6	RR passenger	Carpet	5	Ford Falcon	Motor parts and pine needles	Target
7	Driver	Mat	1	Ford Futura	No visible damage	Matrix
8	FS passenger	Mat	1	Ford Futura	No visible damage	Matrix
9	RR passenger	Mat	1	Ford Futura	No visible damage	Nil
10	FS passenger	Carpet	5	Mitsubishi Colt	No visible damage	Simple
11	Driver	Mat	2	Mitsubishi Colt	No visible damage	Simple
12	LR passenger	Carpet	5	Mitsubishi Colt	No visible damage	Simple
13	FS passenger	Carpet	6	Holden Camira	Front driver side damage	Simple
14	LR passenger	Carpet	6	Holden Camira	Front driver side damage	Simple
15	RR passenger	Carpet	6	Holden Camira	Front driver side damage	Nil
16	Driver	Carpet	6	Holden Camira	Front driver side damage	Nil
17	Driver	Carpet	1	Toyota Corona	No visible damage	Matrix
18	FS passenger	Carpet	1	Toyota Corona	No visible damage	Simple
19	RR passenger	Carpet	6	Toyota Corona	No visible damage	Simple
20	LR passenger	Carpet	6	Toyota Corona	No visible damage	Nil
21	FS passenger	Carpet	1	Holden Commodore	Front driver side damage	Matrix/target
22	LR passenger	Carpet	1	Holden Commodore	Front driver side damage	Simple
23	Driver	Mat	3	Mitsubishi Lancer	Rear left side damage	Simple
24	Driver	Mat	4	Honda Civic	No visible damage	Matrix/target
25	RR passenger	Mat	4	Honda Civic	No visible damage	Matrix
26	LR passenger	Mat	4	Honda Civic	No visible damage	Matrix
27	FS passenger	Mat	4	Honda Civic	No visible damage	Matrix
28	Driver	Mat	2	Ford Falcon Ute	Front driver side damage	Simple
29	FS passenger	Mat	2	Ford Falcon Ute	Front driver side damage	Nil
30	Driver	Mat	7	Toyota Corolla	Rear right side damage	Simple
31	FS passenger	Mat	7	Toyota Corolla	Rear right side damage	Simple
32	Driver	Mat	7	Toyota Celica	No visible damage	Matrix
33	FS passenger	Carpet	4	Toyota Celica	No visible damage	Matrix/target
34	RR passenger	Carpet	2	Seat Ibiza	No visible damage	Target
35	LR passenger	Carpet	2	Seat Ibiza	No visible damage	Target
36	Driver	Mat	2	Seat Ibiza	No visible damage	Target
37	FS passenger	Mat	2	Holden Commodore	Front left side damage	Nil
38	FS passenger	Mat	4	Mazda 929	No visible damage	Nil
39	Driver	Mat	4	Mazda 929	No visible damage	Simple
40	Driver	Mat	1	Mitsubishi Magna	Rear left side damage	Nil
41	RR passenger	Mat	1	Mitsubishi Magna	Rear left side damage	Nil
42	FS passenger	Mat	1	Mitsubishi Magna	Rear left side damage	Simple
43	Driver	Mat	2	Holden Commodore	Front damage	Matrix
44	FS passenger	Mat	2	Holden Commodore	Glass fragments throughout	Matrix
45	LR passenger	Mat	2	Holden Commodore	Interior of vehicle	Matrix
46	RR passenger	Mat	2	Holden Commodore	No windscreen	Matrix
47	Driver	Mat	2	Mazda 626	Rear damage	Matrix/target
48	FS passenger	Mat	2	Mazda 626	Rear bumper bar in back seat	Matrix/target
49	LR passenger	Mat	2	Mazda 626	Rear bumper bar in back seat	Matrix
50	RR passenger	Mat	2	Mazda 626	Rear bumper bar in back seat	Matrix
51	Driver	Mat	1	Ford Laser	No visible damage	Simple
52	FS passenger	Mat	1	Ford Laser	No visible damage	Nil
53	LR passenger	Mat	1	Ford Laser	No visible damage	Nil
54	RR passenger	Mat	1	Ford Laser	No visible damage	Nil
55	Driver	Mat	3	Holden Berlina	Rear left window and door	Matrix/target
56	FS passenger	Mat	3	Holden Berlina	damaged, glass fragments	Nil
57	LR passenger	Mat	3	Holden Berlina	throughout interior	Simple

Table 5 (*Continued*)

No.	Position	Substrate	Type	Vehicle	Condition	Result
58	RR passenger	Mat	3	Holden Berlina	Throughout interior	Simple
59	Driver	Mat	6	Honda Prelude	Left side damage	Simple
60	FS passenger	Mat	2	Mitsubishi Magna	Rear damage	Petrol
61	LR passenger	Mat	2	Mitsubishi Magna	Rear damage	Matrix
62	RR passenger	Mat	2	Mitsubishi Magna	Rear damage	Matrix
63	FS passenger	Mat	2	Toyota Camry	Front damage	Petrol
64	LR passenger	Mat	2	Toyota Camry	Front damage	Simple
65	RR passenger	Mat	2	Toyota Camry	Front damage	Target
66	Driver	Mat	7	Honda Prelude	Front damage	Simple
67	FS passenger	Mat	7	Honda Prelude	Front damage	Simple
68	Driver	Mat	7	Daihatsu Charade	Rear damage	Petrol
69	FS passenger	Mat	7	Daihatsu Charade	Rear damage	Target
70	Driver	Mat	7	Nissan Pulsar	Rear damage	Nil
71	FS passenger	Mat	7	Nissan Pulsar	Rear damage	Petrol
72	Driver	Mat	4	Nissan Pulsar	Front damage	Nil
73	FS passenger	Mat	4	Nissan Pulsar	Front damage	Nil
74	LR passenger	Mat	4	Nissan Pulsar	Front damage	Nil
75	RR passenger	Mat	4	Nissan Pulsar	Front damage	Nil
76	Driver	Mat	4	Holden Barina	Front damage	Matrix
77	FS passenger	Mat	1	Holden Barina	Front damage	Nil
78	RR passenger	Mat	4	Holden Barina	Front damage	Matrix
79	Driver	Mat	3	Nissan Bluebird	Front damage, driver window open	Matrix
80	FS passenger	Mat	2	Holden Commodore	Front damage	Matrix/target
81	RR passenger	Mat	2	Holden Commodore	Front damage	Simple
82	LR passenger	Mat	2	Holden Commodore	Mouldy orange stuck to carpet	Target
83	Driver	Mat	7	Honda Civic	Front damage	Target
84	FS passenger	Mat	7	Honda Civic	Front damage	Target
85	LR passenger	Mat	7	Honda Civic	Front damage	Target
86	Driver	Mat	4	Mitsubishi Magna	Rear damage	Matrix
87	FS passenger	Mat	4	Mitsubishi Magna	Driver window open	Matrix
88	LR passenger	Mat	4	Mitsubishi Magna	Driver window open	Matrix
89	RR passenger	Mat	4	Mitsubishi Magna	Driver window open	Matrix
90	Driver	Mat	3	Nissan Bluebird	Front damage, driver window open	Matrix
91	Driver	Mat	1	Nissan Pulsar	Rear left side damage	Simple
92	Driver	Mat	1	Mazda 626	Front damage	Matrix
93	FS passenger	Mat	1	Mazda 626	Front damage	Matrix
94	Driver	Mat	1	Toyota Camry	Rear damage	Simple
95	FS passenger	Mat	8	Toyota Camry	Rear damage	Target
96	Driver	Mat	2	Ford Falcon	Front damage	Target
97	FS passenger	Mat	2	Ford Falcon	Petrol can in centre console	Target
98	LR passenger	Mat	2	Ford Falcon	Petrol can in centre console	Target
99	RR passenger	Mat	2	Ford Falcon	Petrol can in centre console	Petrol
100	Driver	Mat	9	Holden Barina	Front right side damage	Target
101	FS passenger	Mat	8	Holden Barina	Front right side damage	Simple
102	Driver	Mat	4	Holden Barina	No passenger window	Matrix
103	Driver	Mat	1	Toyota Corolla	Front and driver side damage	Matrix
104	FS passenger	Mat	1	Toyota Corolla	Driver window missing	Matrix
105	LR passenger	Mat	1	Toyota Corolla	Glass fragments on driver floor	Matrix
106	RR passenger	Mat	1	Toyota Corolla	Assorted rubbish throughout	Matrix
107	Driver	Mat	2	Holden Barina	No visible damage	Target
108	FS passenger	Mat	2	Holden Barina	No visible damage	Simple
109	LR passenger	Mat	2	Holden Barina	No visible damage	Simple
110	RR passenger	Mat	2	Holden Barina	No visible damage	Simple
111	Driver	Mat	4	Honda Integra	Rear damage	Matrix
112	FS passenger	Mat	4	Honda Integra	Driver window open	Matrix
113	LR passenger	Mat	4	Honda Integra	Front passenger window open	Matrix
114	RR passenger	Mat	4	Honda Integra	Front passenger window open	Matrix
115	Driver	Mat	3	Ford Falcon	Front left side damage	Simple

Table 5 (*Continued*)

No.	Position	Substrate	Type	Vehicle	Condition	Result
116	FS passenger	Mat	3	Ford Falcon	Front left side damage	Nil
117	LR passenger	Mat	3	Ford Falcon	Front left side damage	Simple
118	RR passenger	Mat	3	Ford Falcon	Front left side damage	Nil
119	Driver	Mat	4	Holden Commodore	Driver side damage	Matrix
120	FS passenger	Mat	4	Holden Commodore	Driver window open	Matrix
121	RR passenger	Mat	4	Holden Commodore	Driver window open	Matrix
122	RR passenger	Mat	1	Daihatsu Charade	Front and driver damage	Matrix
123	Driver	Mat	1	Daihatsu Charade	Driver window open	Matrix
124	FS passenger	Mat	1	Daihatsu Charade	Driver window open	Matrix
125	LR passenger	Mat	1	Daihatsu Charade	Driver window open	Matrix
126	Driver	Mat	4	Toyota Cressida	Front damage	Matrix
127	RR passenger	Carpet	5	Toyota Corona	Front and rear damage	Nil
128	LR passenger	Carpet	5	Toyota Corona	Front and rear damage	Simple
129	FS passenger	Carpet	5	Toyota Corona	Front and rear damage	Nil
130	Driver	Carpet	5	Toyota Corona	Front and rear damage	Nil
131	LR passenger	Carpet	5	Holden Barina	No boot or bonnet	Simple
132	RR passenger	Carpet	5	Holden Barina	No boot or bonnet	Simple
133	Driver	Carpet	5	Holden Barina	No boot or bonnet	Nil
134	FS passenger	Carpet	5	Holden Barina	No boot or bonnet	Nil
135	Driver	Mat	4	Ford Festiva	No windscreen	Matrix
136	RR passenger	Mat	4	Ford Festiva	All windows open	Matrix
137	RR passenger	Carpet	5	Ford Festiva	Front and roof damage	Simple
138	Driver	Carpet	5	Ford Festiva	Front and roof damage	Simple
139	RR passenger	Carpet	5	Toyota Corolla	Front damage	Nil
140	LR passenger	Carpet	5	Toyota Corolla	Driver window open	Simple
141	FS passenger	Carpet	5	Toyota Corolla	Driver window open	Simple
142	Driver	Mat	9	Toyota Corolla	Driver window open	Simple
143	LR passenger	Carpet	5	Suzuki Swift	Front and driver side damage	Simple
144	Driver	Carpet	5	Toyota Cressida	Front damage, windows open	Simple
145	RR passenger	Carpet	5	Toyota Cressida	Left side doors missing	Nil
146	Driver	Carpet	5	Honda Civic	Front damage	Nil
147	LR passenger	Carpet	5	Honda Civic	Front damage	Simple
148	FS passenger	Carpet	5	Honda Civic	Front damage	Simple
149	RR passenger	Carpet	5	Honda Civic	Front damage	Simple
150	Driver	Mat	2	Ford Laser	Rear damage, rear screen missing	Nil

passenger well. Fig. 8 illustrates a typical chromatographic profile exhibited by these samples. The profile is similar to that of partially evaporated petrol, however, not all the target compounds are present as required by the criteria chosen for this study. In these samples, either target compounds are absent, e.g. the methyl-naphthalenes (at least one is required), or they are present in quantities lower than the levels required in this study, to be considered conclusive. As such, for the purposes of this study, such profiles cannot be classified as representing petrol.

Table 6
Background profiles of unknown history samples

Background profile	Percent of carpet samples	Percent of car mat samples	Percent of total samples
No major peaks	29	17	21
Simple chromatogram	50	22	29
MI	7	40	30
MI and target compounds	5	5	5
Target compounds	7	11	11
Petrol	2	5	4

Four of the samples exhibiting this background chromatographic profile were obtained from vehicles in which a carpet/mat sample from a different well was found to contain petrol. Two of these samples were removed from a vehicle that had a petrol can sitting in the centre console, and one was taken from a vehicle with a distinct odour of petrol, and minor burn marks on the car seat surfaces. It is possible that petrol was present on these samples, however, if so, it was in amounts below the level necessary for confirmation.

3.6. Petrol

Only 6 of the 150 samples conclusively exhibited the presence of petrol. Over 50% of these samples originated from the front passenger well. Of the six unknown samples

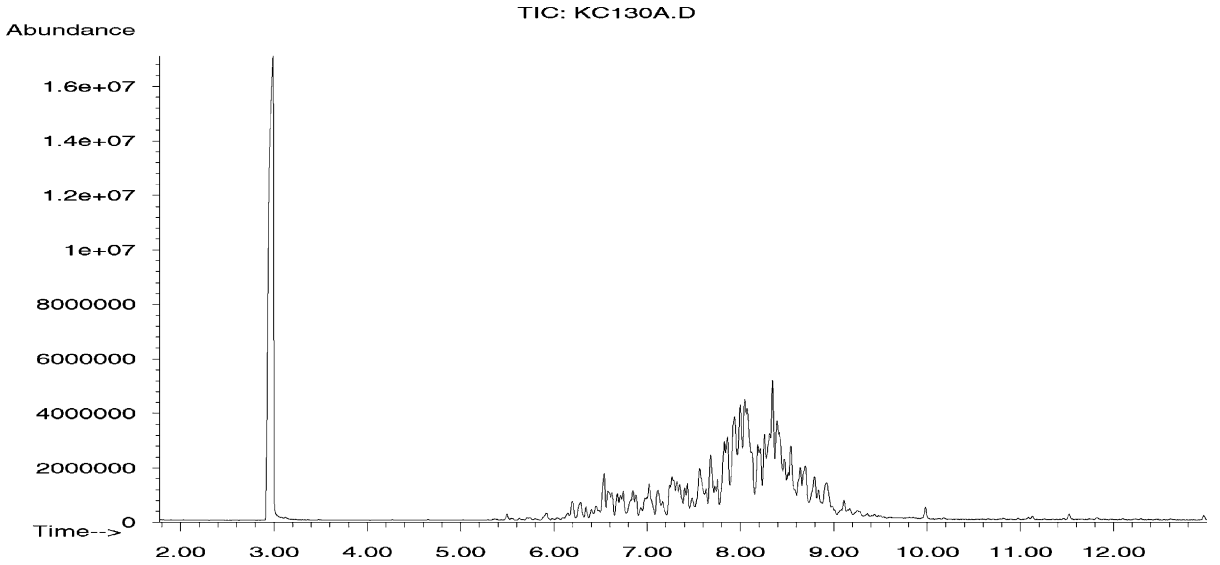

Fig. 7. Total ion chromatogram of car mat sample (type 4) showing significant matrix interference.

that were found to contain petrol, only one exhibited the presence of high levels. This was also the only car carpet (as opposed to car mat) sample to contain petrol. The significant levels found on this carpet may have been the result of intentional application, as the vehicle had a very strong odour of petrol, and there were minor burn marks on the car seat surfaces. The remaining five samples exhibited low levels of petrol, and all showed similar profiles.

The chromatographic profiles exhibited by all of the positive samples appear to be more similar to evaporated petrol than fresh petrol. There is a decrease in intensity of the more volatile compounds, and a corresponding increase in intensity of the less volatile, heavier compounds.

Of the samples that contained petrol or target compounds, excluding those where was a possible explanation, the majority originated from the front passenger well. Six of the eight samples (75%) were from this area, while the remaining two samples were from the driver area. All of these samples were carpet car mats with a rubber backing (types 2, 7 and 8).

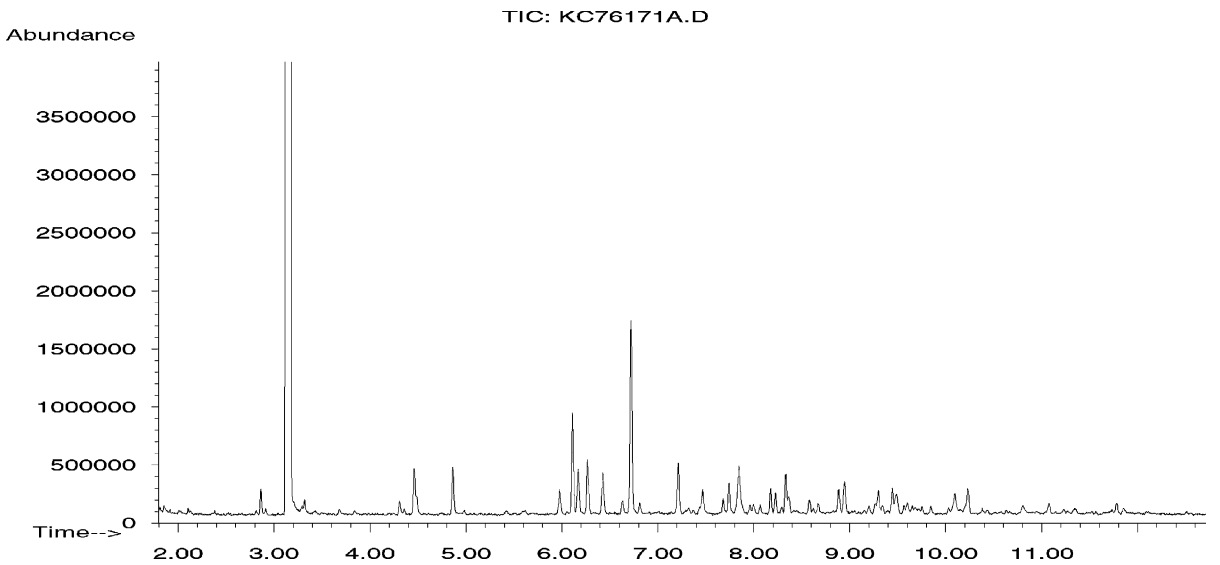

Fig. 8. Magnified chromatographic profile of samples exhibiting numerous target compounds.

4. Discussion

4.1. Persistence study

Only two of the carpet samples in the persistence study exhibited detectable levels of petrol after having known volumes added and being left to evaporate at room temperature. Both of these samples had the largest volume of petrol added (100 μl), and were left for the shortest period of time (24 h). This differs from the results reported by Folkman et al. [12] for a similar persistence study. In their study, petrol was still detectable on a carpet sample 7 days after 100 μl of petrol had been added. A possible explanation for this dissimilarity is the difference in the temperatures the samples were exposed to. The temperature in the above study ranged from 5 to 15 °C, whereas the temperature range in this study was 22–22.5 °C. Higher temperatures significantly accelerate the rate of evaporation of the more volatile components of petrol, thus, decreasing the time period that petrol will be detectable. The samples in this study were stored indoors, compared to outdoor exposure for the study reported by Folkman et al. [12].

The degree of petrol evaporation from carpet car mats is significant even after just 24 h. The petrol identified on the two positive samples showed chromatographic profiles of petrol that was more than 60% evaporated. This fact significantly increases the value of finding fresh or slightly evaporated petrol on carpets in motor vehicles in the general population.

The level of background interference exhibited by all of the persistence samples was quite significant when first analysed. As time passed, however, this background level reduced considerably. The difference between the levels present at 1 day, 1 week and 1 month, was significant. By the end of the longest exposure period, very few compounds present in the initial background chromatographic profile could actually be identified. As such, the degree to which the background interference would complicate the identification of petrol on these carpet mats also decreases.

4.2. Known history study

None of the samples used in the known history study contained petrol after insertion into a motor vehicle, however, 47% of the samples did exhibit the presence of new compounds not present in their initial chromatographic profile. The largest number of new compounds on any one carpet was eight, however, the majority of carpets exhibited less than three new compounds. Of these new compounds, the xylenes were the most prevalent, being present in all mats showing the presence of new compounds. Only three of the car mats exhibited a number of the other target compounds diagnostic for petrol, with the highest number present being seven compounds. These target compounds were amongst the most volatile, and usually most abundant compounds in fresh petrol.

Of the three mats exhibiting a significant number of target compounds, the mat with the most compounds (eight) was placed in a vehicle owned and driven by a mechanic. The fact that this person regularly comes into contact with petroleum products during the course of their working day may account for the result. This observation is in contrast to the findings reported by Folkman et al. [12]. In their study, the clothing of a service station attendant was examined for the presence of petrol, but none was found. It was not stated whether any of the target compounds diagnostic for petrol were present on the clothing.

The other two mats exhibiting a significant number of target compounds were in vehicles that were filled with petrol more than once per week. However, the levels of target compounds present in these samples were significantly lower than those found on the mechanic's mat.

A tentative conclusion that may be drawn from this study is that the likelihood of finding petrol target compounds on vehicle carpet is affected by the level of contact the driver has with petrol. Possible factors are whether the driver has an occupation that involves contact with petroleum products, and how frequent this contact is. Similarly, the frequency with which the driver fills the petrol tank may also affect the levels of target compounds present, but to a more limited degree.

None of the mats placed in vehicles that were filled less than once per week exhibited the presence of new compounds. However, the converse is not necessarily true. Not all of the mats placed in vehicles filled at least once per week exhibited the presence of new compounds. Twenty-nine percent of mats in this category did not exhibit any new compounds at all, indicating that the frequency of fuel entry does not dictate the likelihood of target compounds being present.

Three of the car mats were found to contain limonene, a common solvent in carpet cleaning products. These mats were in the only three vehicles to be cleaned during the insertion period, which could account for the presence of this compound. Limonene is also commonly found in adhesives. Eucalyptol was found in the mats from two vehicles, and α-pinene was also present in one of these two vehicles. These compounds are naturally occurring oils found in pine and eucalyptus, and are also commonly used as scenting agents. The drivers of both vehicles reported going bushwalking during the insertion period, and may have transported wood chips and the like into the vehicle. Another possible source of these compounds is their use as a scenting agent, as both drivers reported using products containing these compounds. These findings indicate the effect the usage of the vehicle, and the behaviour of the occupants, can have on the composition of volatiles in the carpet.

All of the mats obtained directly from the manufacturer exhibited significant levels of background interference. However, as with the mats used in the persistence study, all of the samples showed a reduction in this level of background interference after the insertion period. In addition,

the greater the length of the insertion period, the lower the level of interference remaining.

4.3. Unknown history study

The analysis of 41 car carpet and 109 carpet mats collected from 54 different motor vehicles resulted in the finding of six samples containing petrol. Of these samples, there were two cases where there was a possible explanation for the presence of petrol.

- One sample (driver carpet, multi-coloured padding, adhesive layer evident) contained a significant amount of petrol compared to the other samples containing petrol, and it was removed from a vehicle with a strong odour of petrol and burns to the seat material. This vehicle may have been involved in a fire in which petrol was used as an accelerant. A sample (sample 6) from the rear right passenger carpet from this vehicle also exhibited a significant number of the target compounds diagnostic of petrol.
- The second sample (rear right passenger mat, rubber backing) was removed from a vehicle in which a petrol can (containing a liquid smelling of petrol) was observed sitting in the centre console, between the front seats. This can may have previously been positioned in the rear passenger well, or in some way contaminated the surrounding area with petrol. The driver and front passenger mats (samples 96 and 97) from this vehicle exhibited significant numbers of target compounds for the identification of petrol, possible also due to the presence of this petrol can.

There was no obvious reason why trace levels of petrol were found on the remaining four samples with unknown history. It is possible that this petrol was the result of transfer via shoes or the vehicle's fuel storage and transport system, however, as no background history is known, this cannot be determined conclusively. All four of these samples were mats with a rubber backing, three from the front passenger well, and one from the driver well.

Out of the above 150 samples, 7 with unknown history contained a number of target compounds required for the identification of petrol. However, they did not satisfy the requirements set for this study, and thus, could not be classified as containing petrol. As described previously, there were possible explanations for the presence of target compounds in three cases (samples 6, 96 and 97). The remaining four samples that exhibited a considerable number of petrol target compounds were all mats with a rubber backing. Three of the mats were removed from the front passenger wells, and one from the driver well.

A higher percentage of front passenger mats exhibited the presence of petrol than samples from any other position in the vehicle. Front passenger mats also accounted for the greatest number of samples exhibiting a majority of petrol target compounds. As no history was available for these samples, no conclusions may be drawn regarding possible sources.

None of the carpet/mat sample types exhibited only one kind of background chromatographic profile in the unknown history study, indicating the need for comparison sampling in the analysis of fire debris. There was, however, a significant difference between the chromatographic profiles of car carpet and car mats. The majority of car carpet samples (79%) exhibited easily interpreted chromatographic profiles or no major compounds, while only 39% of car mats had these profiles. Both carpet and mat samples from motor vehicles can exhibit matrix interference, however, the percentage of carpet samples exhibiting matrix interference was much lower than the percentage of car mats (12 compared to 45%).

As with the samples exhibiting matrix interference in the known history and persistence studies, background interference was generally present as a large unresolved group of peaks, consisting mainly of branched or straight-chain aliphatics (saturated and unsaturated). While such a chromatographic profile cannot be confused with that of petrol, it can complicate the identification of some target compounds characteristic of petrol. As the matrix interference occurs in the same chromatographic region as the tetramethylbenzenes, it can mask their presence. Of the total number of unknown history samples, 35% exhibited such background interference, while the vast majority (50%) exhibited no major compounds or easily interpretable chromatographic profiles.

The observation in both the persistence study and the known history samples that the level of background interference decreases over time may be a possible explanation for the fact that 50% of the unknown history samples exhibited little or no background interference.

5. Conclusions

Materials, such as carpet, which are manufactured from petroleum feed stocks, can decompose when heated to produce volatile organic compounds. This study has confirmed that carpet removed from motor vehicles in the general population can exhibit some of the compounds that are diagnostic for petrol residues. However, in the majority of cases, the chromatographic patterns produced by these components can be easily distinguished from those produced by petrol. These findings are in keeping with those of Lentini and et al. [4] in their study examining the background interferences produced by commonly encountered products.

Several authors [20,21] have addressed the need for the collection of comparison samples at the fire scene. The fact that 35% of carpet samples of unknown history, and 71% of samples with known history analysed during this study produced potentially complicating background interferences confirms the requirement for comparison sampling. Comparison samples allow the analyst to more easily discern

whether the recovered components originated from an accelerant or from the matrix itself.

Previously uncontaminated new carpet car mats are unlikely to exhibit petrol profiles after insertion into a vehicle for up to 6 weeks. However, if the occupation of the driver involves regular contact with petroleum products, there is a strong possibility that volatile compounds found in petrol will be absorbed by the carpet. The effect of occupation on the likelihood of finding petrol requires further investigation.

Small volumes of petrol (<100 μl) are unlikely to be detected on carpet car mats after 24 h. A volume of 100 μl can be detected after 24 h (1 day), but not after 7 days, when left indoors at room temperature. The petrol residue remaining after 24 h exhibits a chromatographic profile similar to that of more than 60% evaporated petrol.

Of the 'unknown history' carpet samples analysed in this study, 4% (one original vehicle carpet, and five carpet mats) were found to contain petrol at low levels. In all of these cases, the chromatographic profile was similar to that of evaporated petrol. Whether this petrol would be detected after burning, as in the case of a motor vehicle fire, is not known.

All of these findings increase the evidential value of finding significant volumes of fresh or slightly evaporated petrol on carpet products in motor vehicles. Such a finding may indicate the intentional addition of petrol to the vehicle interior, as only trace levels are generally found without good reason.

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